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(54) **DUAL CONNECTIVITY CAPABILITY MODIFICATION**

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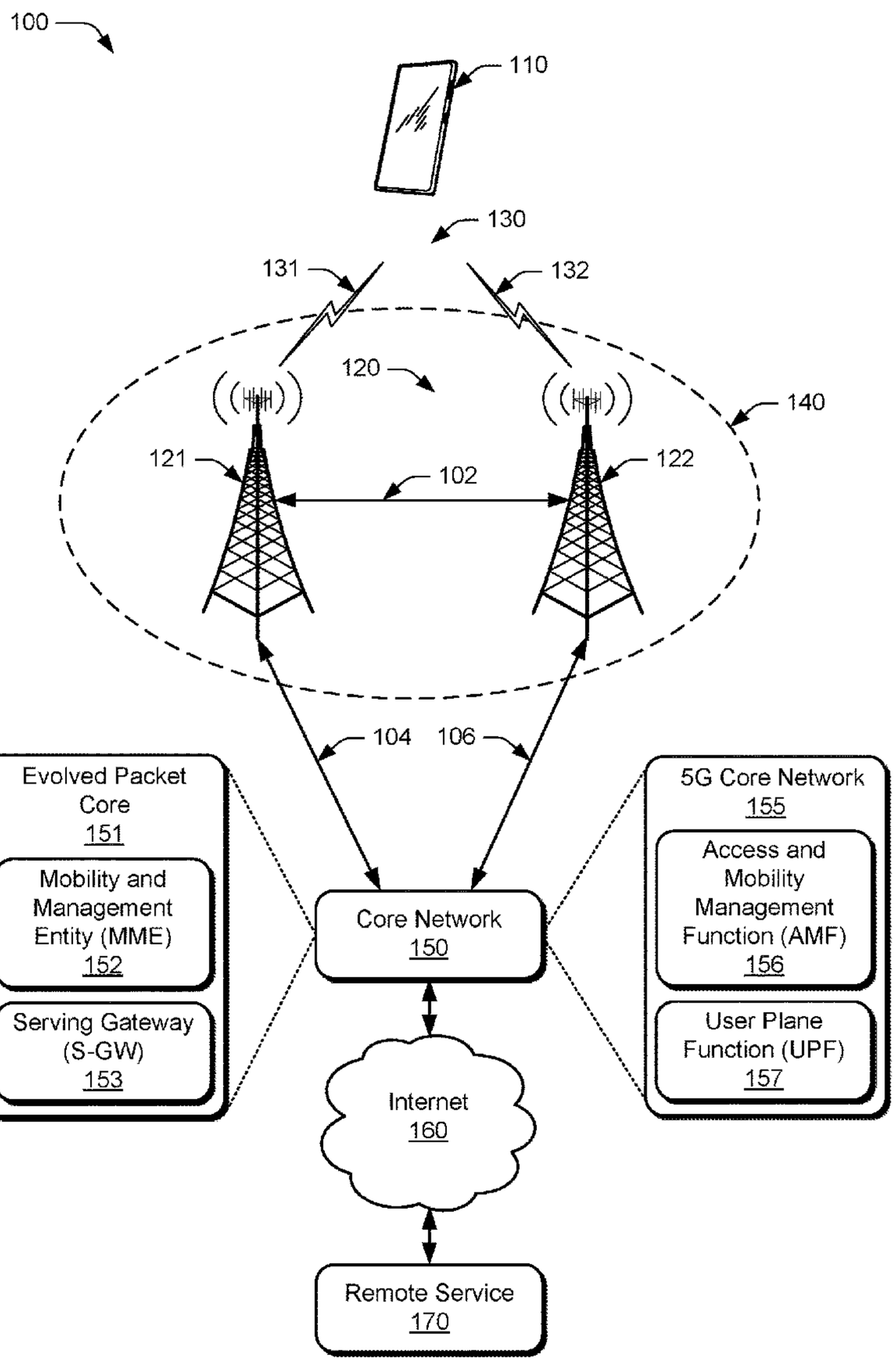
(57) **ABSTRACT**

This document describes techniques and devices for communication of dual connectivity (DC) capability by user equipment (**110**) to a base station (**120**) and a core network (**150**) using signaling of a modification of the DC capability of the UE (**110**) at the physical layer (**306**) or the media access control layer (**308**) to reduce the latency of communicating the modification of the DC capability as compared to using Radio Resource Control layer (**322**) signaling. Signaling a modification of DC capability at the physical layer (**306**) or media access control layer (**308**) enables the UE (**110**) to more quickly respond to issues detected by the UE (**110**), such as thermal management or in-device coexistence interference, that may be mitigated by discontinuing DC communications.



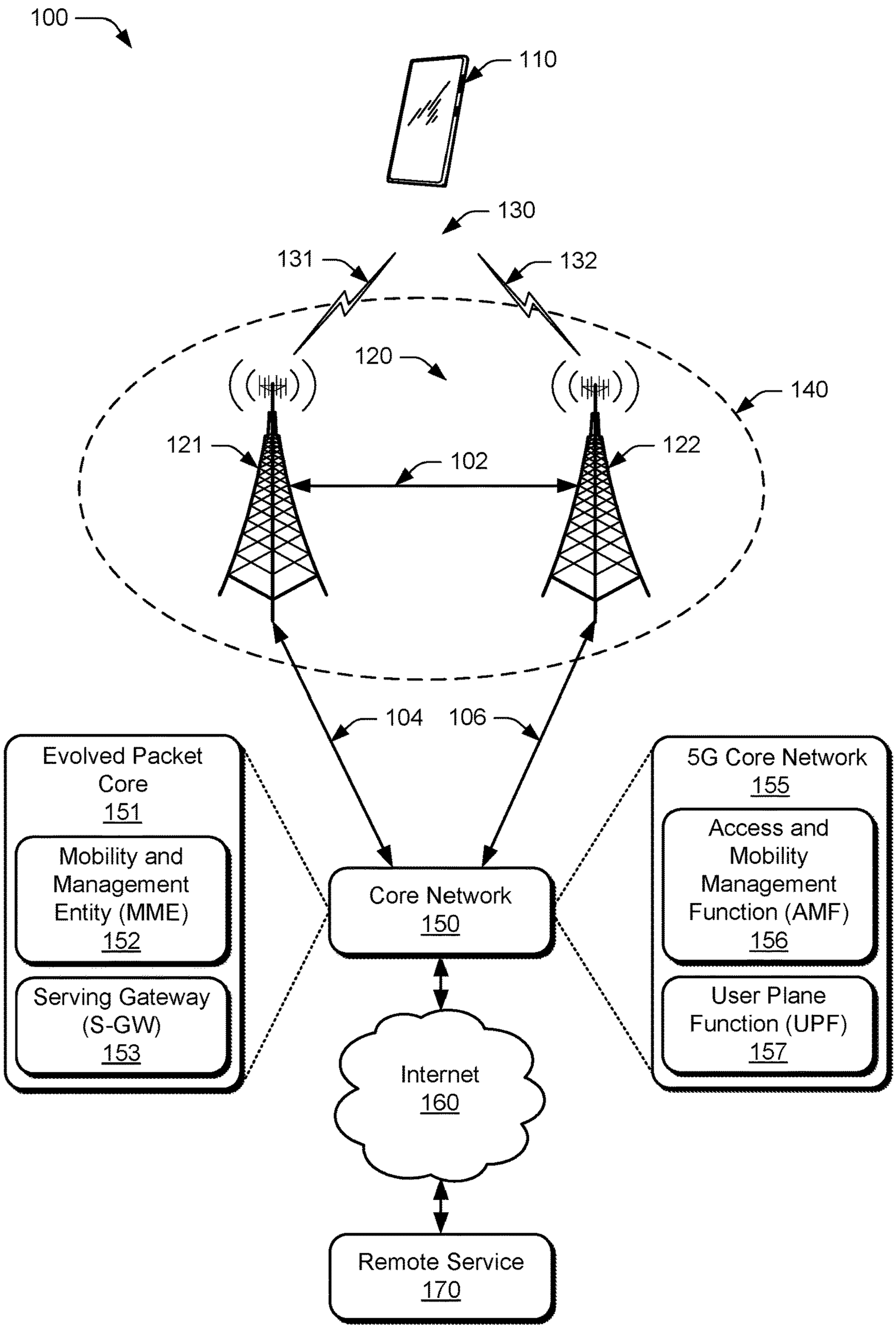

100
110
130
131
132
120
140
121
122
102
104
106
Evolved Packet Core
151
Mobility and Management Entity (MME)
152
Serving Gateway (S-GW)
153
Core Network
150
Internet
160
Remote Service
170
5G Core Network
155
Access and Mobility Management Function (AMF)
156
User Plane Function (UPF)
157

Fig. 1

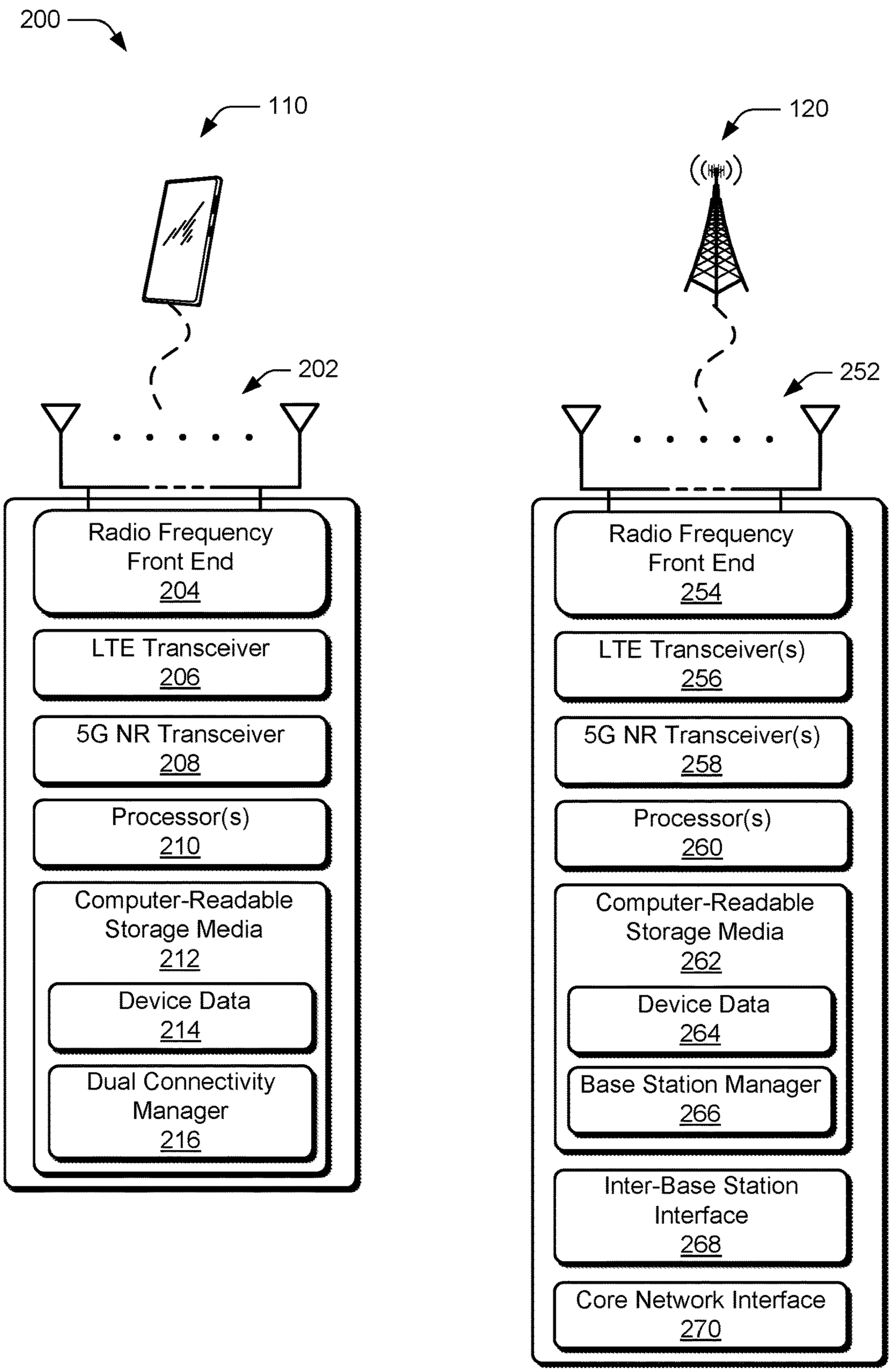

200
110
120
202
252
Radio Frequency Front End 204
LTE Transceiver 206
5G NR Transceiver 208
Processor(s) 210
Computer-Readable Storage Media 212
Device Data 214
Dual Connectivity Manager 216
Radio Frequency Front End 254
LTE Transceiver(s) 256
5G NR Transceiver(s) 258
Processor(s) 260
Computer-Readable Storage Media 262
Device Data 264
Base Station Manager 266
Inter-Base Station Interface 268
Core Network Interface 270

Fig. 2

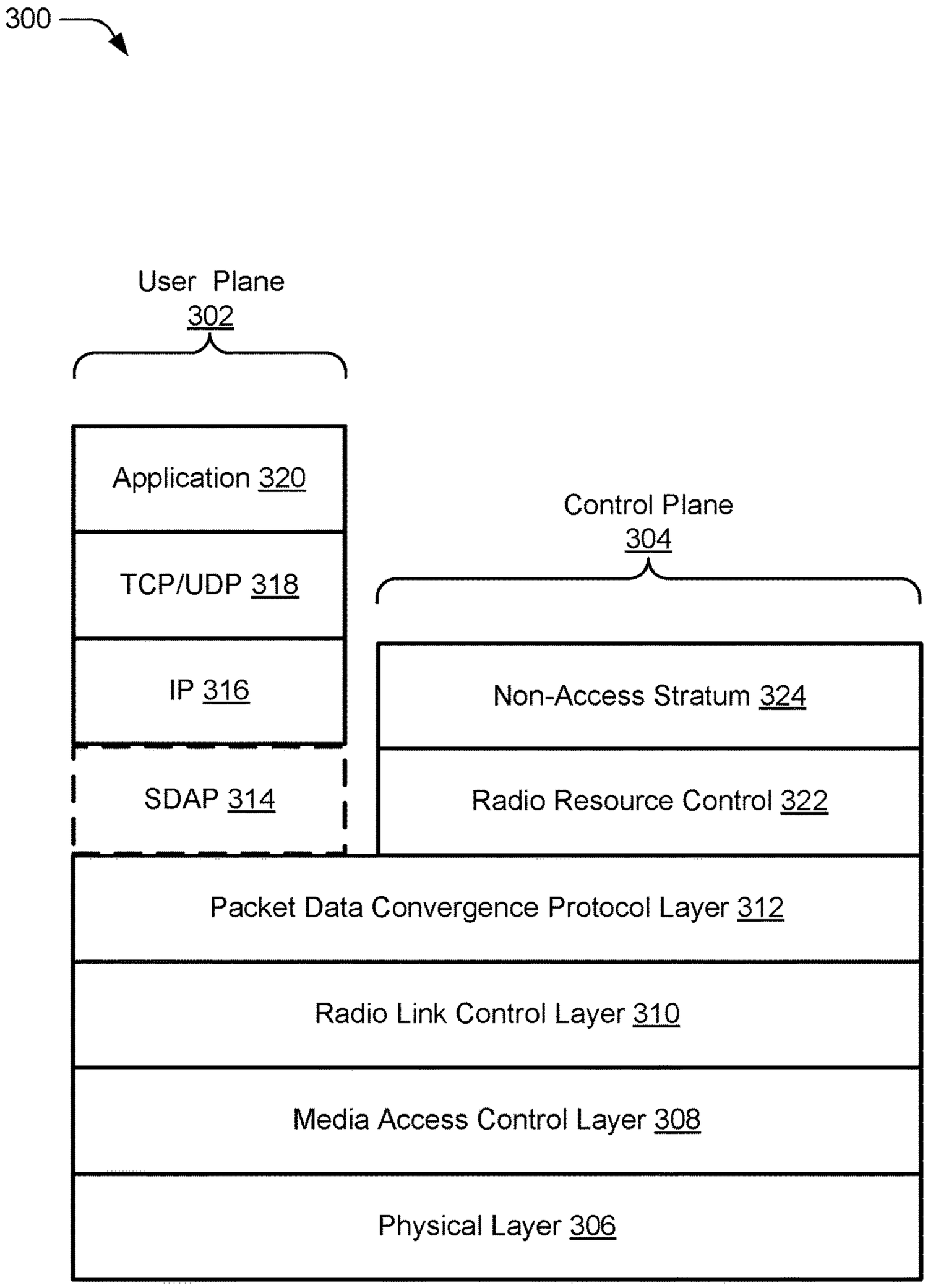

300
User Plane
302
Application 320
TCP/UDP 318
IP 316
SDAP 314
Control Plane
304
Non-Access Stratum 324
Radio Resource Control 322
Packet Data Convergence Protocol Layer 312
Radio Link Control Layer 310
Media Access Control Layer 308
Physical Layer 306

Fig. 3

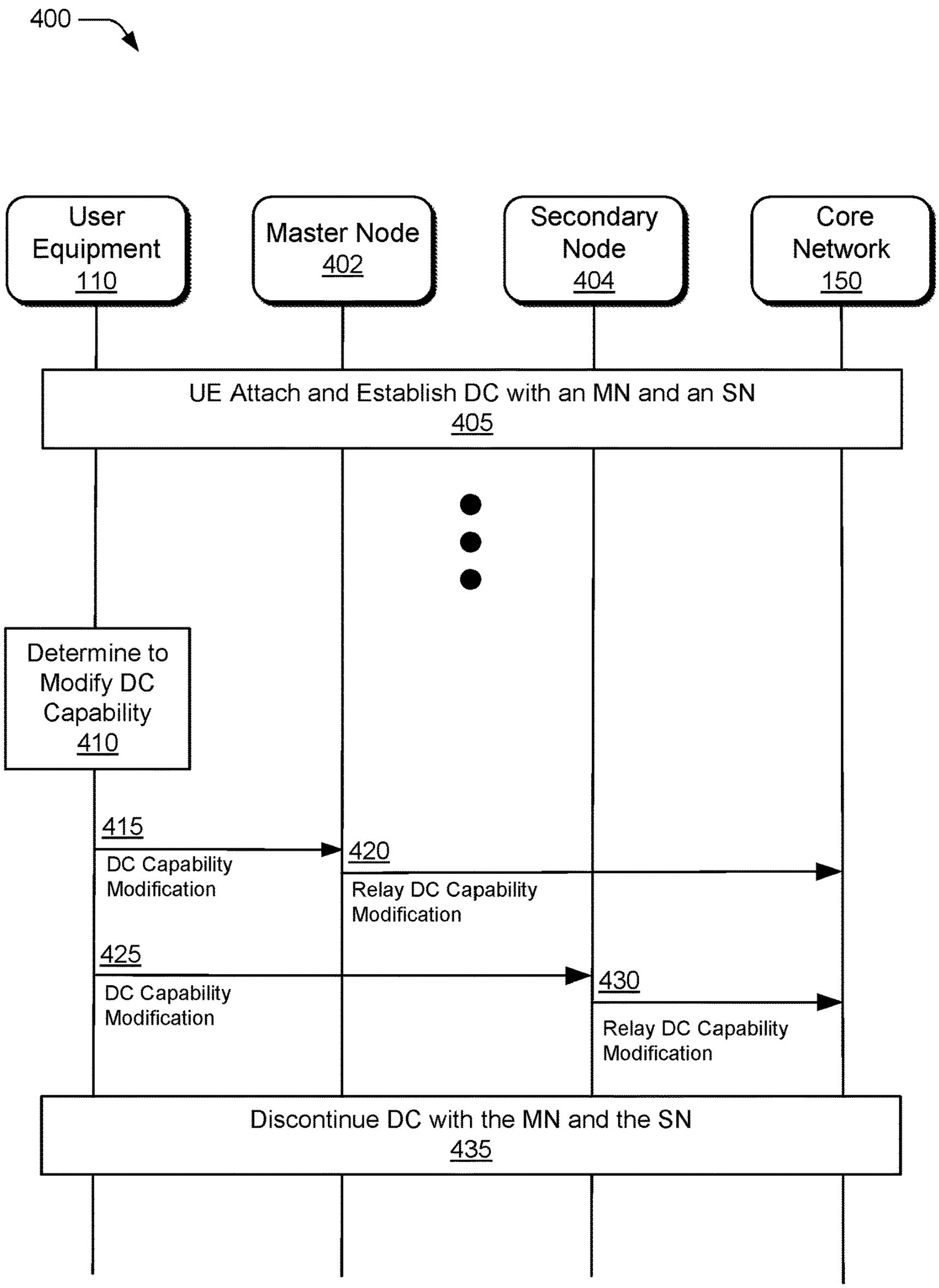

400
User Equipment 110
Master Node 402
Secondary Node 404
Core Network 150
UE Attach and Establish DC with an MN and an SN 405
Determine to Modify DC Capability 410
415
DC Capability Modification
420
Relay DC Capability Modification
425
DC Capability Modification
430
Relay DC Capability Modification
Discontinue DC with the MN and the SN 435

Fig. 4

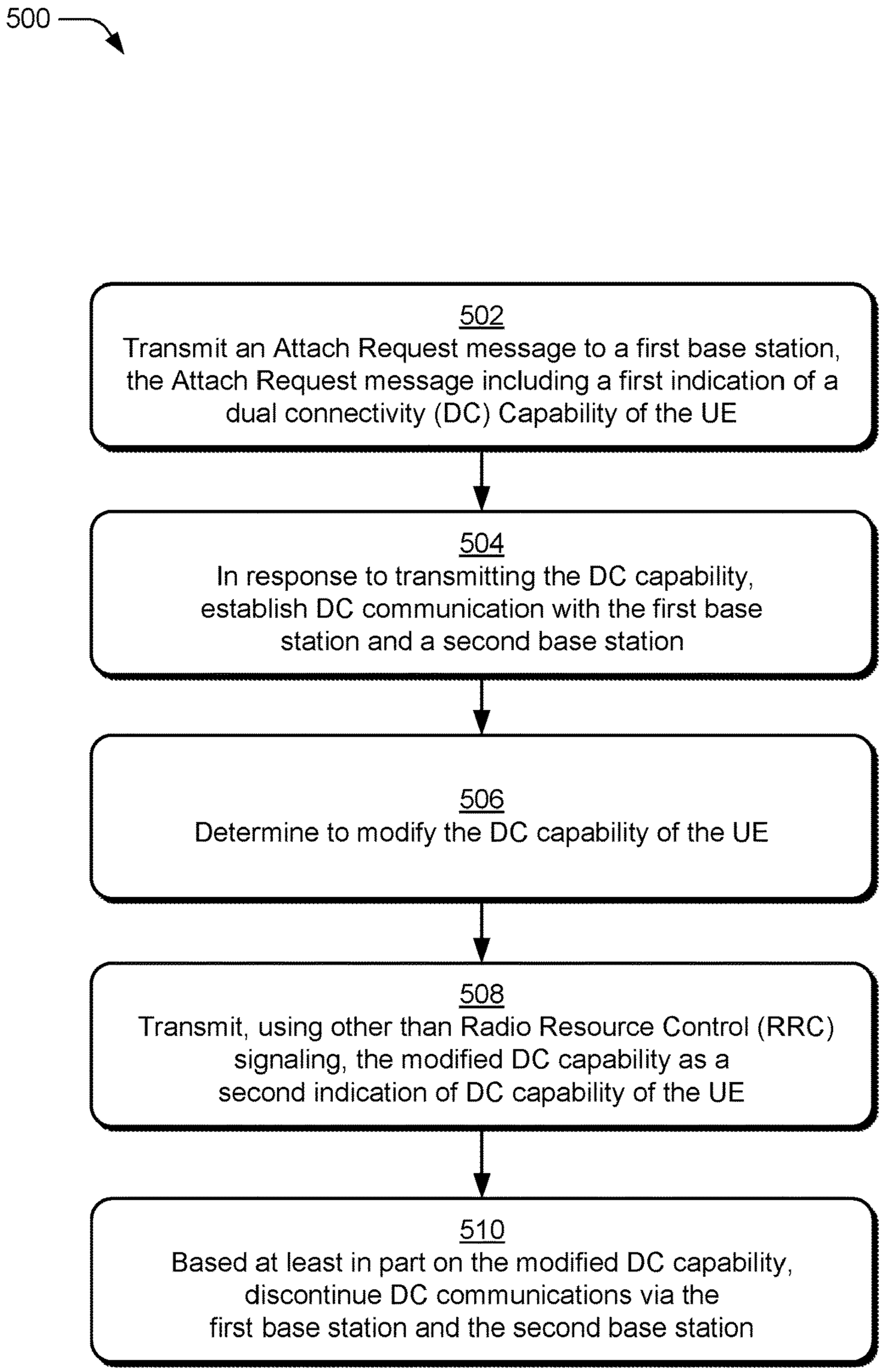

500
502
Transmit an Attach Request message to a first base station, the Attach Request message including a first indication of a dual connectivity (DC) Capability of the UE
504
In response to transmitting the DC capability, establish DC communication with the first base station and a second base station
506
Determine to modify the DC capability of the UE
508
Transmit, using other than Radio Resource Control (RRC) signaling, the modified DC capability as a second indication of DC capability of the UE
510
Based at least in part on the modified DC capability, discontinue DC communications via the first base station and the second base station

Fig. 5

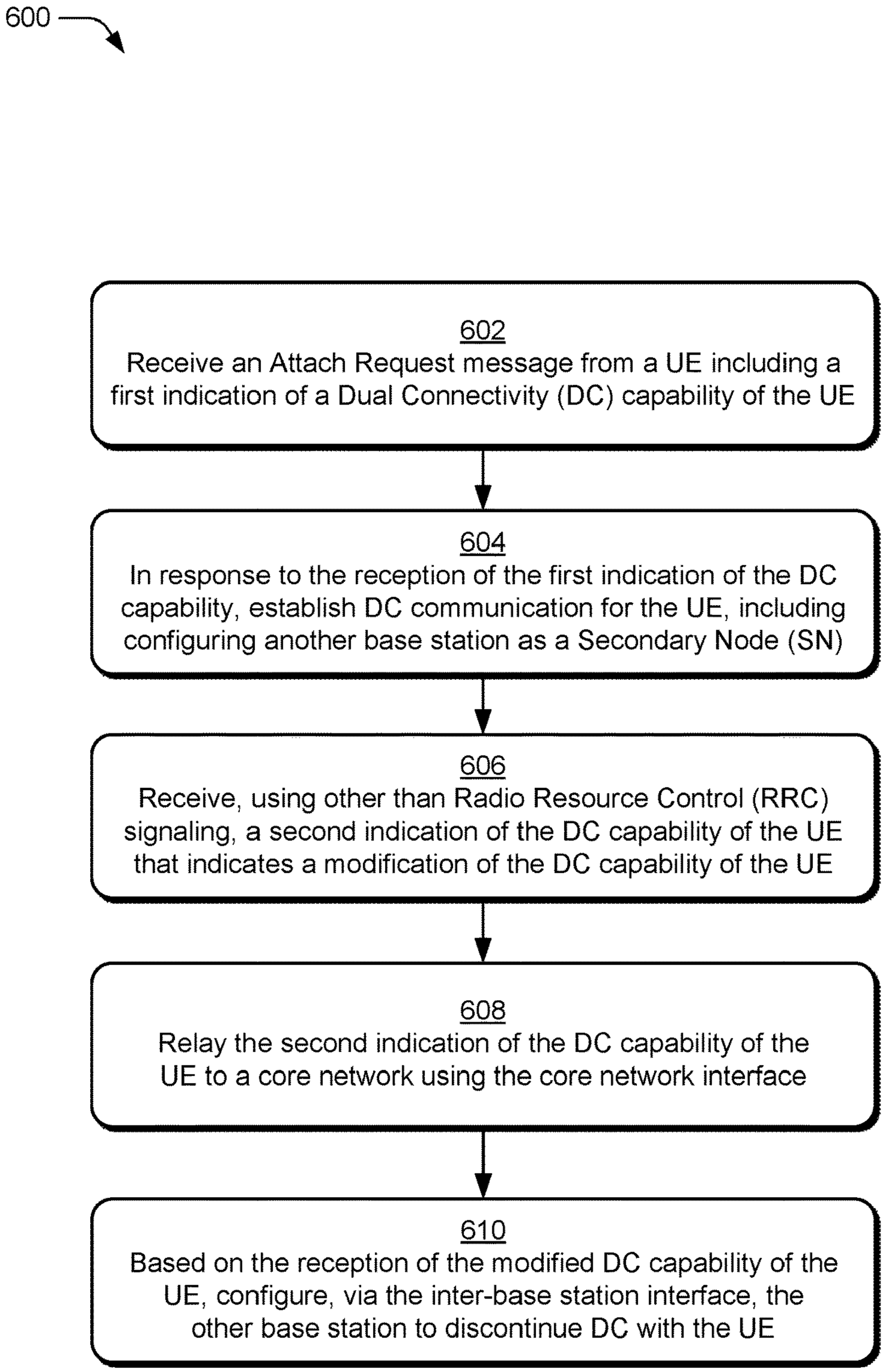

600
602
Receive an Attach Request message from a UE including a first indication of a Dual Connectivity (DC) capability of the UE
604
In response to the reception of the first indication of the DC capability, establish DC communication for the UE, including configuring another base station as a Secondary Node (SN)
606
Receive, using other than Radio Resource Control (RRC) signaling, a second indication of the DC capability of the UE that indicates a modification of the DC capability of the UE
608
Relay the second indication of the DC capability of the UE to a core network using the core network interface
610
Based on the reception of the modified DC capability of the UE, configure, via the inter-base station interface, the other base station to discontinue DC with the UE

Fig. 6

DUAL CONNECTIVITY CAPABILITY MODIFICATION

BACKGROUND

[0001] The evolution of wireless communication to fifth generation (5G) standards and technologies provides higher data rates and greater capacity, with improved reliability and lower latency that enhances mobile broadband services. 5G technologies also provide new classes of services for vehicular networking, fixed wireless broadband, and the Internet of Things (IoT).

[0002] A unified air interface, which utilizes licensed, unlicensed, and shared license radio spectrum in multiple frequency bands is one aspect of enabling the capabilities of 5G systems. The 5G air interface utilizes radio spectrum in bands below 1 GHz (sub-gigahertz), below 6 GHz (sub-6 GHz), and above 6 GHz. Radio spectrum above 6 GHz includes millimeter wave (mmWave) frequency bands that provide wide channel bandwidths to support higher data rates for wireless broadband. Another aspect of enabling the capabilities of 5G systems is the use of Multiple Input Multiple Output (MIMO) antenna systems to beamform signals transmitted between base stations and user equipment to increase the capacity of 5G radio networks.

[0003] To support the transition to 5G networks, multiple radio access technology connectivity enables a user equipment (UE) to simultaneously connect to Evolved Universal Terrestrial Radio Access (E-UTRA) and 5G base stations. The UE indicates its capability for dual connectivity to a base station; however, circumstances may arise, such as thermal management or in-device coexistence interference in which the UE may benefit from rapidly modifying and communicating its capability for dual connectivity.

SUMMARY

[0004] This summary is provided to introduce simplified concepts of dual connectivity capability modification. The simplified concepts are further described below in the Detailed Description. This summary is not intended to identify essential features of the claimed subject matter nor is it intended for use in determining the scope of the claimed subject matter.

[0005] In some aspects, a method for communicating a modification of dual connectivity (DC) capability by a user equipment (UE) in a cellular network is described in which the UE transmits an Attach Request message to a first base station, the Attach Request message including a first indication of a DC capability of the UE. In response to transmitting the DC capability, the UE establishes DC communication with the first base station and a second base station. The UE determines to modify the DC capability of the UE and transmits, using other than Radio Resource Control (RRC) signaling, the modified DC capability as a second indication of DC capability of the UE. Based at least in part on the modified DC capability of the UE, the UE discontinues DC communications via the first base station and the second base station.

[0006] In other aspects, a base station configured as a Master Node (MN) for Dual Connectivity (DC) communication includes a radio frequency (RF) transceiver, a core network interface, an inter-base station interface, and a processor and memory system to implement a base station manager application. The base station manager application is configured to receive, via the RF transceiver, an Attach Request message from a user equipment (UE) including a first indication of a Dual Connectivity (DC) capability of the UE and, in response to the reception of the first indication of the DC capability of the UE, establish DC communication for the UE including configuring another base station as a Secondary Node (SN) via the inter-base station interface. The base station manager application is configured to receive, using other than Radio Resource Control (RRC) signaling, a second indication of the DC capability of the UE that indicates a modification of the DC capability of the UE and relay the second indication of the DC capability of the UE to a core network using the core network interface. Based on the reception of the modified DC capability of the UE, the base station manager application configures, via the inter-base station interface, the other base station to discontinue DC with the UE.

[0007] In further aspects, a method for communicating a user equipment (UE) capability for multi-Radio Access Technology (Multi-RAT) Dual Connectivity (DC) by a base station is described, in which the base station receives an Attach Request message from the UE including a first indication of a DC capability of the UE and, in response to the receiving the DC capability of the UE, establishes DC communication for the UE including configuring another base station as a Secondary Node (SN). The base station receives, using other than Radio Resource Control (RRC) signaling, a second indication of the DC capability of the UE that indicates a modification of the DC capability of the UE and relays the second indication of the DC capability to a core network. Based on the receiving the modified DC capability of the UE, the base station configures, via the inter-base station interface, the other base station to discontinue DC with the UE.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Aspects of dual connectivity capability modification are described with reference to the following drawings. The same numbers are used throughout the drawings to reference like features and components:

[0009] FIG. **1** illustrates an example wireless network environment in which various aspects of dual connectivity capability modification can be implemented.

[0010] FIG. **2** illustrates an example device diagram that can implement various aspects of dual connectivity capability modification.

[0011] FIG. **3** illustrates an example block diagram of a wireless network stack model that characterizes a communication system with which various aspects of dual connectivity capability modification can be implemented.

[0012] FIG. **4** illustrates example data and control transactions between devices engaged in dual connectivity in accordance with various aspects of dual connectivity capability modification.

[0013] FIG. **5** illustrates an example method of dual connectivity capability modification as generally related to determining and communicating, by the user equipment, a modification of DC capability in accordance with aspects of the techniques described herein.

[0014] FIG. **6** illustrates an example method of dual connectivity capability modification as generally related to a base station receiving an indication of a modified DC capability from a UE in accordance with aspects of the techniques described herein.

DETAILED DESCRIPTION

Overview

[0015] This document describes techniques and devices for the communication of dual connectivity (DC) capability by user equipment (UE) to a base station and a core network using signaling of a modification of the DC capability of the UE at the physical layer or the media access control layer to reduce the latency of communicating the modification of the DC capability as compared to using Radio Resource Control layer signaling. Signaling a modification of DC capability at the physical layer or media access control layer enables the UE to more quickly respond to issues detected by the UE, such as thermal management or in-device coexistence issues, that may be mitigated by discontinuing DC communications.

[0016] A UE may have the capability to use Dual Connectivity (DC) to simultaneously communicate with an Evolved Universal Terrestrial Radio Access (E-UTRA) base station and a Fifth Generation (5G) New Radio (NR) base station. This is generically called Multi-RAT Dual Connectivity (MR-DC). When the E-UTRA base station act as a Master Node (MN) and the 5G NR base station acts as a Secondary Node (SN) for DC communication, and both the E-UTRA base station and the NR base station are connected to a Mobility Management Entity (MME) and a Serving Gateway (S-GW) in an Evolved Packet Core (EPC) network, this provides E-UTRA-NR Dual Connectivity (EN-DC) for the UE. Alternatively, when the E-UTRA base station acts as the MN and the 5G NR base station acts as the SN for DC communication, and both the E-UTRA base station and the NR base station are connected to an Access and Mobility Management Function (AMF) and a User Plane Function (UPF) in a 5G core network, the MR-DC configuration is referred to as NGEN-DC. A third MR-DC configuration, called NE-DC, involves a 5G NR base station acting as a MN and an E-UTRA base station acting as a SN with both base stations connected to a 5G core network.

[0017] Additionally, the techniques for dual connectivity capability modification described herein apply equally to single-RAT dual connectivity in cases where the MN and the SN are both E-UTRA base stations or the MN and SN are both 5G NR base stations. In the case where the MN and SN are E-UTRA base stations, both base stations are connected to the MME and the S-GW in the EPC network. In the other case where the MN and SN are 5G NR base stations, both base stations are connected to the AMF and the UPF in the 5GC network.

[0018] The UE provides an indication in an Attach Request message to the core network, via either the MN or the SN, that it has the capability to communicate using DC. During operations using DC, there may be circumstances detected by the UE, such as in-device coexistence issues, overheating, or the like, that may cause the UE to determine to discontinue operating using DC to address the detected issue. When the detected issue resolves, the UE may determine to resume DC operation.

[0019] The UE can signal a change in DC capability to the MN or SN using Radio Resource Control signaling. Although the UE continues to have the technical ability to operate using MR-DC, this capability signaling indicates that the UE's current capacity for DC operation has changed.

[0020] To reduce the latency of signaling the change in DC capability, the UE may signal the change in DC capability in Uplink Control Information (UCI) at a physical level entity or using a Control Element (CE) at a Media Access Control (MAC) level entity to enable resources for the DC communications to be released more quickly. Alternatively, the MN may allocate a Random Access Channel (RACH) resource to signal DC capability modification, in which case the UE may transmit the modification to the DC capability using the allocated RACH resource via a Physical Random Access Channel (PRACH).

[0021] While features and concepts of the described systems and methods for dual connectivity capability modification can be implemented in any number of different environments, systems, devices, and/or various configurations, aspects of dual connectivity capability modification are described in the context of the following example devices, systems, and configurations.

Example Environment

[0022] FIG. **1** illustrates an example environment **100** which includes a user equipment **110** (UE **110**) that can communicate with one or more base stations **120** (illustrated as base stations **121** and **122**) through one or more wireless communication links **130** (wireless link **130**), illustrated as wireless links **131** and **132**. In this example, the user equipment **110** is implemented as a smartphone. Although illustrated as a smartphone, the user equipment **110** may be implemented as any suitable computing or electronic device, such as a mobile communication device, a modem, cellular phone, gaming device, navigation device, media device, laptop computer, desktop computer, tablet computer, smart appliance, vehicle-based communication system, and the like. The base stations **120** (e.g., an Evolved Universal Terrestrial Radio Access Network Node B, E-UTRAN Node B, evolved Node B, eNodeB, eNB, Next Generation Node B, gNode B, gNB, or the like) may be implemented in a macrocell, microcell, small cell, picocell, and the like, or any combination thereof.

[0023] The base stations **120** communicate with the UE **110** via the wireless links **131** and **132**, which may be implemented as any suitable type of wireless link. The wireless links **131** and **132** can include a downlink of data and control information communicated from the base stations **120** to the UE **110**, an uplink of other data and control information communicated from the UE **110** to the base stations **120**, or both. The wireless links **130** may include one or more wireless links or bearers implemented using any suitable communication protocol or standard, or combination of communication protocols or standards such as 3rd Generation Partnership Project Long-Term Evolution (3GPP LTE), Fifth Generation New Radio (5G NR), and so forth. Multiple wireless links **130** may be aggregated in a carrier aggregation to provide a higher data rate for the UE **110**. Multiple wireless links **130** from multiple base stations **120** may be configured for Coordinated Multipoint (CoMP) communication with the UE **110**, as well as dual connectivity, such as single-RAT LTE-LTE or NR-NR dual connectivity or Multi-Radio Access Technology (Multi-RAT) Dual Connectivity (MR-DC) including EN-DC, NGEN-DC, and NE-DC.

[0024] The base stations **120** are collectively a Radio Access Network **140** (RAN, Evolved Universal Terrestrial Radio Access Network, E-UTRAN, 5G NR RAN or NR RAN). The base stations **121** and **122** are connected to a core network **150** via control-plane and user-plane interfaces at

links **104** and **106**. In EN-DC, the core network **150** is an Evolved Packet Core **151** (EPC **151**) that includes a Mobility Management Entity **152** (MME **152**) that provides control-plane functions such as registration and authentication of multiple UE **110**, authorization, mobility management, or the like. The EPC **151** includes a Serving Gateway **153** (S-GW **153**) that relays user-plane data between UEs **110** and the Internet **160** and a remote service **170**. In NGEN-DC and NE-DC, the core network **150** is a 5G core network **155** (5GC **155**) that includes an Access and Mobility Management Function **156** (AMF **156**) that provides control-plane functions such as registration and authentication of multiple UE **110**, authorization, mobility management, or the like. The 5GC **155** includes a User Plane Function **157** (UPF **157**) that relays user-plane data between UEs **110** and the Internet **160** and the remote service **170**.

[0025] In one aspect, when the UE **110** is using EN-DC, the UE **110** communicates with the base station **121**, which acts as a Master Node (MN), and the wireless link **131** is an E-UTRA link. The UE **110** also communicates with the base station **122**, which acts as a Secondary Node (SN) and the wireless link **132** is a 5G NR link. At link **102** the base station **121** and the base station **122** can communicate user-plane and control-plane data via an X2 interface. The base station **121** communicates control plane information with the MME **152** in the EPC **151** via an S1-MME interface and relays control-plane information to the base station **122** via the X2 interface.

[0026] In another aspect, when the UE **110** is using NGEN-DC, the UE **110** communicates with the base station **121**, which acts as the Master Node (MN), and the wireless link **131** is an E-UTRA link. At link **102** the base station **121** and the base station **122** can communicate user-plane and control-plane data via an Xn interface. The base station **121** communicates control plane information with the AMF **156** in the 5GC **155** via an NG-C interface and relays control-plane information to the base station **122** via the Xn interface.

[0027] In a further aspect, when the UE **110** is using NE-DC, the UE **110** communicates with the base station **121**, which is a 5G NR base station, and acts as the Master Node (MN) and the wireless link **131** is an 5G NR link. The base station **122**, which is an E-UTRA base station, acts as the Secondary Node (SN) and the wireless link **132** in an E-UTRA link. At link **102** the base station **121** and the base station **122** can communicate user-plane and control-plane data via the Xn interface. The base station **121** communicates control plane information with the AMF **156** in the 5GC **155** via the NG-C interface and relays control-plane information to the base station **122** via the Xn interface.

[0028] Turning from an MR-DC configuration, the FIG. **1** environment may also represent a single-RAT DC configuration. In one type of single-RAT DC situation, both base stations **121**, **122** are E-UTRA base stations and can communicate user-plane and control-plane data via an X2 interface over link **102**, and both base stations link **104**, **106** to an EPC **151**. In another type of single-RAT DC situation, both base stations **121**, **122** are 5G NR base stations and can communicate user-plane and control-plane data via an Xn interface over link **102**, and both base stations link **104**, **106** to a 5G core network **155**.

[0029] FIG. **2** illustrates an example device diagram **200** of the user equipment **110**, the base station **121**, and the neighbor base station **122**. The user equipment **110**, the base station **121**, and the neighbor base station **122** may include additional functions and interfaces that are omitted from FIG. **2** for the sake of clarity. The user equipment **110** includes antennas **202**, a radio frequency front end **204** (RF front end **204**), an LTE transceiver **206**, and a 5G NR transceiver **208** for communicating with base stations **120**. The RF front end **204** of the user equipment **110** can couple or connect the LTE transceiver **206**, and the 5G NR transceiver **208** to the antennas **202** to facilitate various types of wireless communication. The LTE transceiver **206** and the 5G NR transceiver **208** may include sensor circuitry and algorithms for measuring characteristics of radio signals and/or sensing in-device coexistence issues. The antennas **202** of the user equipment **110** may include an array of multiple antennas that are configured similar to or differently from each other. The antennas **202** and the RF front end **204** can be tuned to, and/or be tunable to, one or more frequency bands defined by the 3GPP LTE and 5G NR communication standards and implemented by the LTE transceiver **206**, and/or the 5G NR transceiver **208**. Additionally, the antennas **202**, the RF front end **204**, the LTE transceiver **206**, and/or the 5G NR transceiver **208** may be configured to support beamforming for the transmission and reception of communications with the base station **121**, the base station **122**, or both. By way of example and not limitation, the antennas **202** and the RF front end **204** can be implemented for operation in sub-gigahertz bands, sub-6 GHZ bands, and/or above 6 GHz bands that are defined by the 3GPP LTE and 5G NR communication standards.

[0030] The user equipment **110** also includes processor(s) **210** and computer-readable storage media **212** (CRM **212**). The processor **210** may be a single core processor or a multiple core processor composed of a variety of materials, such as silicon, polysilicon, high-K dielectric, copper, and so on. The computer-readable storage media described herein excludes propagating signals. CRM **212** may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or Flash memory useable to store device data **214** of the user equipment **110**. The device data **214** includes user data, multimedia data, beamforming codebooks, applications, and/or an operating system of the user equipment **110**, which are executable by processor(s) **210** to enable user-plane communication, control-plane signaling, and user interaction with the user equipment **110**.

[0031] CRM **212** also includes a dual connectivity manager **216**. Alternately or additionally, the dual connectivity manager **216** may be implemented in whole or part as hardware logic or circuitry integrated with or separate from other components of the user equipment **110**. In at least some aspects, the dual connectivity manager **216** configures the RF front end **204**, the LTE transceiver **206**, and/or the 5G NR transceiver **208** to implement the techniques for dual connectivity capability modification described herein. The dual connectivity manager **216** may receive input from other elements in the UE **110**, such as the RF front end **204**, the LTE transceiver **206**, the 5G NR transceiver **208**, a temperature sensor (not shown), other radio transceivers (not shown), such as a Wireless Local Area Network (WLAN) transceiver and/or a Bluetooth™ transceiver, or other sensors (not shown), to determine when to signal a change in DC capability.

[0032] The device diagram for the base stations **120**, shown in FIG. **2**, includes a representative single network node (e.g., a gNode B). The functionality of the base stations **120** may be distributed across multiple network nodes or devices and may be distributed in any fashion suitable to perform the functions described herein. The base stations **120** include antennas **252**, a radio frequency front end **254** (RF front end **254**), one or more LTE transceivers **256**, and/or one or more 5G NR transceivers **258** for communicating with the UE **110**. The RF front end **254** of the base stations **120** can couple or connect the LTE transceivers **256** and the 5G NR transceivers **258** to the antennas **252** to facilitate various types of wireless communication. The antennas **252** of the base stations **120** may include an array of multiple antennas that are configured similar to or differently from each other. The antennas **252** and the RF front end **254** can be tuned to, and/or be tunable to, one or more frequency band defined by the 3GPP LTE and 5G NR communication standards, and implemented by the LTE transceivers **256**, and/or the 5G NR transceivers **258**. Additionally, the antennas **252**, the RF front end **254**, the LTE transceivers **256**, and/or the 5G NR transceivers **258** may be configured to support beamforming, such as Massive-MIMO, for the transmission and reception of communications with the UE **110**.

[0033] The base stations **120** also include processor(s) **260** and computer-readable storage media **262** (CRM **262**). The processor **260** may be a single core processor or a multiple core processor composed of a variety of materials, such as silicon, polysilicon, high-K dielectric, copper, and so on. CRM **262** may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or Flash memory useable to store device data **264** of the base stations **120**. The device data **264** includes network scheduling data, radio resource management data, beamforming codebooks, applications, and/or an operating system of the base stations **120**, which are executable by processor(s) **260** to enable communication with the UE **110**.

[0034] CRM **262** also includes a base station manager **266**. Alternately or additionally, the base station manager **266** may be implemented in whole or part as hardware logic or circuitry integrated with or separate from other components of the base stations **120**. In at least some aspects, the base station manager **266** configures the LTE transceivers **256** and the 5G NR transceivers **258** for communication with the UE **110**, as well as communication with a core network. The base stations **120** include an inter-base station interface **268**, such as an Xn and/or X2 interface, which the base station manager **266** configures to exchange user-plane and control-plane data between another base station **120** per FIG. **1** link **102**, to manage the communication of the base stations **120** with the UE **110**. The base stations **120** include a core network interface **270**, such as an S1 or NG interface, which the base station manager **266** configures to exchange user-plane and control-plane data with core network functions and entities per FIG. **1** links **104**, **106**.

User Plane and Control Plane Signaling

[0035] FIG. **3** illustrates an example block diagram of a wireless network stack model **300** that characterizes a communication system for the example environment **100**, in which various aspects of dual connectivity capability modification can be implemented. The wireless network stack **300** includes a user plane **302** and a control plane **304**. Upper layers of the user plane **302** and the control plane **304**, share common lower layers in the wireless network stack **300**. Wireless devices such as the UE **110** or base stations **120** implement each layer as an entity for communication with another device using the protocols defined for the layer. For example, a UE **110** uses a Packet Data Convergence Protocol (PDCP) entity to communicate to a peer PDCP entity in a base station **120** using the PDCP.

[0036] The shared lower layers include a physical layer **306** (PHY layer **306**), a Media Access Control layer **308** (MAC layer **308**), a Radio Link Control layer **310** (RLC layer **310**), and a Packet Data Convergence Protocol layer **312** (PDCP layer **312**). The physical layer **306** provides hardware specifications for devices that communicate with each other. As such, the physical layer **306** establishes how devices connect to each other, assists in managing how communication resources are shared among devices, and the like.

[0037] The MAC layer **308** specifies how data is transferred between devices. Generally, the MAC layer **308** provides a way in which data packets being transmitted are encoded and decoded into bits as part of a transmission protocol.

[0038] The RLC layer **310** provides data transfer services to higher layers in the wireless network stack **300**. Generally, the RLC layer **310** provides error correction, packet segmentation and reassembly, and management of data transfers in various modes, such as acknowledged, unacknowledged, or transparent modes.

[0039] The PDCP layer **312** provides data transfer services to higher layers in the wireless network stack **300**. Generally, the PDCP layer **312** provides transfer of user plane **302** and control plane **304** data, header compression, ciphering, and integrity protection.

[0040] Above the PDCP layer **312**, the wireless network stack splits into the user-plane stack **302** and the control-plane stack **304**. The user plane **302** layers include an optional Service Data Adaptation Protocol layer **314** (SDAP **314**), an Internet Protocol layer **316** (IP **316**), a Transmission Control Protocol/User Datagram Protocol layer **318** (TCP/UDP **318**), and an application **320** that transfer data via the wireless link **130**. The optional SDAP layer **314** is present in 5G NR networks and maps a Quality of Service (QoS) flow for each data radio bearer and marks QoS flow identifiers in uplink and downlink data packets for each packet data session. The IP layer **316** specifies how the data from the application **320** is transferred to a destination node. The TCP/UDP layer **318** is used to verify that data packets intended to be transferred to the destination node reached the destination node, using either TCP or UDP for data transfers by the application **320**.

[0041] The control plane **304** includes Radio Resource Control **322** (RRC **322**) and a Non-Access Stratum **324** (NAS **324**). The RRC **322** establishes and releases connections and radio bearers, broadcasts system information, performs power control, and so forth. The NAS **324** provides support for mobility management and packet data bearer contexts between the user equipment **110** and entities or functions in the core network, such as the Mobility Management Entity **152** (MME **152**), the Access and Mobility Management Function **156** (AMF **156**), or the like.

[0042] In the UE **110**, each layer in both the user plane **302** and the control plane **304** of the wireless network stack **300** interacts with a corresponding peer layer or entity in a base station **120**, a core network entity or function, and/or a remote service, to support user applications and control operation of the UE **110** in the RAN **140**.

Dual Connectivity Capability Modification

[0043] FIG. **4** illustrates details of example data and control transactions between devices engaged in dual connectivity of the user equipment **110** from a Master Node (MN) **402** (e.g., the base station **121**) and a Secondary Node **404** (e.g., the base station **122**) in accordance with various aspects of dual connectivity capability modification. In aspects, the UE **110**, the MN **402**, the SN **404**, and the core network **150** establish MR-DC (EN-DC, NGEN-DC, or NE-DC) or single-RAT DC (LTE-LTE or NR-NR) between the UE **110**, and the MN **402** and the SN **404**, at **405**. The UE **110** includes an indication in an Attach Request message to signal the core network **150** that the UE **110** is capable of establishing DC communications.

[0044] After establishing and operating for a period of time using DC, the UE **110** determines to indicate that there is a change in its DC capability at **410**. For example, the UE **110** may determine that there is an in-device coexistence issue between radio transceivers in the UE **110** that can be mitigated by discontinuing DC communications, the UE **110** may determine that there is a thermal management (e.g., overheating) problem that can be addressed by discontinuing DC communications, or the like.

[0045] At **415** the UE **110** sends an indication of a modification of the DC capability of the UE **110** to the MN **402**. Instead of using RRC layer signaling, the UE **110** sends the indication of the modification of the DC capability in UCI via a Physical Uplink Control Channel (PUCCH) or in a MAC CE to the MN **402**. Alternatively, the MN **402** may allocate a Random Access Channel (RACH) resource to signal DC capability modification, in which case the UE **110** may transmit the indication of the modification of the DC capability using the allocated RACH resource via a Physical Random Access Channel (PRACH). By using the UCI, MAC CE, or PRACH instead of RRC signaling to communicate the modification of its DC capability, the UE **110** can reduce the signaling latency to communicate the DC capability modification from approximately 10 mSec to less than approximately 1 mSec.

[0046] At **420** the MN **402** forwards the modified DC capability of the UE **110** to the core network **150**. In a first example, in EN-DC with an EPC **151**, the MN **402** (an E-UTRA base station) uses an S1-C-modified-EN-DC-Capability message to relay the modification of the DC capability of the UE **110** to the MME **152** in the EPC **151** via the S1-MME interface. In a second example, in NGEN-DC with an 5GC **155**, the MN **402** (an E-UTRA base station) uses an NG-C-modified-NGEN-DC-Capability message to relay the modification of the DC capability of the UE **110** to the AMF **156** in the 5GC **155** via the NG-C interface. In a third example, in NE-DC with an 5GC **155**, the MN **402** (a 5G NR base station) uses an NG-C-modified-NE-DC-Capability message to relay the modification of the DC capability of the UE **110** to the AMF **156** in the 5GC **155** via the NG-C interface. In a fourth example, in LTE-LTE DC with an EPC **151**, the MN **402** (an E-UTRA base station) uses an S1-C-modified-LTE-LTE-DC-Capability message to relay the modification of the DC capability of the UE **110** to the MME **152** in the EPC **151** via the S1-MME interface. In a fifth example, in NR-NR DC with an 5GC **155**, the MN **402** (a 5G NR base station) uses an NG-C-modified-NR-NR-DC-Capability message to relay the modification of the DC capability of the UE **110** to the AMF **156** in the 5GC **155** via the NG-C interface.

[0047] Alternatively or additionally, at **425** the UE **110** sends an indication of a modification of the DC capability of the UE **110** to the SN **404**. The UE **110** sends the indication of the modification of the DC capability in UCI via a PUCCH or in a MAC CE to the SN **404**. Alternatively, the SN **404** may allocate a Random Access Channel (RACH) resource to signal DC capability modification, in which case the UE **110** may transmit the modification to the DC capability using the allocated RACH resource via a PRACH. In another alternative, the UE **110** may use any 5G NR uplink carrier, such as a supplemental uplink, to send the indication of the modification of the DC capability in the UCI or a MAC CE.

[0048] At **430**, the SN **404** forwards the modified DC capability of the UE **110** to the core network **150**. Continuing with the first example, in EN-DC with an EPC **151**, the SN **404** (a 5G NR base station) uses an S1-C-modified-EN-DC-Capability message to relay the modification of the DC capability of the UE **110** to the MME **152** in the EPC **151**. Continuing with the second example, in NGEN-DC with an 5GC **155**, the SN **404** (a 5G NR base station) uses an NG-C-modified-NGEN-DC-Capability message to relay the modification of the DC capability of the UE **110** to the AMF **156** in the 5GC **155** via the NG-C interface. Continuing with the third example, in NE-DC with an 5GC **155**, the SN **404** (an E-UTRA base station) uses an NG-C-modified-NE-DC-Capability message to relay the modification of the DC capability of the UE **110** to the AMF **156** in the 5GC **155** via the NG-C interface. Continuing with the fourth example, in LTE-LTE DC with an EPC **151**, the SN **402** (an E-UTRA base station) uses an S1-C-modified-LTE-LTE-DC-Capability message to relay the modification of the DC capability of the UE **110** to the MME **152** in the EPC **151**. Continuing with the fifth example, in NR-NR DC with an 5GC **155**, the SN **402** (a 5G NR base station) uses an NG-C-modified-NR-NR-DC-Capability message to relay the modification of the DC capability of the UE **110** to the AMF **156** in the 5GC **155** via the NG-C interface. Additionally or alternatively in these examples, the DC capability messages from the SN **404** may be relayed by the MN **202** via the Xn-C and/or the NG-C interfaces.

[0049] At **435**, after transmitting the indication of the modified DC capability, the UE **110** discontinues operation using MR-DC. The MN **402** and/or the SN **404** discontinue MR-DC with the UE **110** and can release resources associated with the DC communications.

[0050] Additionally or optionally the UE may further modify the DC capability to reestablish DC communications. The UE **110** may use RRC signaling, the UCI, the MAC CE, or the allocated RACH resource to indicate that it is again capable of DC, such as when an in-device coexistence or thermal problem has been resolved at the UE **110**.

Example Methods

[0051] Example methods **500** and **600** are described with reference to FIGS. **5** and **6** in accordance with one or more

aspects of dual connectivity capability modification. The order in which the method blocks are described are not intended to be construed as a limitation, and any number of the described method blocks can be skipped or combined in any order to implement a method or an alternate method. Generally, any of the components, modules, methods, and operations described herein can be implemented using software, firmware, hardware (e.g., fixed logic circuitry), manual processing, or any combination thereof. Some operations of the example methods may be described in the general context of executable instructions stored on computer-readable storage memory that is local and/or remote to a computer processing system, and implementations can include software applications, programs, functions, and the like. Alternatively or in addition, any of the functionality described herein can be performed, at least in part, by one or more hardware logic components, such as, and without limitation, Field-programmable Gate Arrays (FPGAs), Application-specific Integrated Circuits (ASICs), Application-specific Standard Products (ASSPs), System-on-a-chip systems (SoCs), Complex Programmable Logic Devices (CPLDs), and the like.

[0052] FIG. **5** illustrates example method(s) **500** of dual connectivity capability modification as generally related to determining and communicating, by the user equipment **110**, a modification of DC capability.

[0053] At block **502**, a user equipment (e.g., UE **110**) transmits an Attach Request message to a first base station (e.g., base station **121**), the Attach Request message including a first indication of a DC capability of the UE.

[0054] At block **504**, in response to transmitting the DC capability, the UE establishes DC communication with the first base station and a second base station (e.g., base station **122**).

[0055] At block **506**, the UE determines to modify the DC capability of the UE. For example, the UE determines to discontinue DC communications to address an in-device coexistence or thermal management issue in the UE.

[0056] At block **508**, the UE transmits, using other than Radio Resource Control (RRC) signaling, the modified DC capability as a second indication of DC capability of the UE. For example, the UE transmits the second indication in UCI, MAC CE, or using an allocated RACH resource via a PRACH.

[0057] At block **510**, based at least in part on the modified DC capability, the UE discontinues DC communications via the first base station and the second base station.

[0058] FIG. **6** illustrates example method(s) **600** of dual connectivity capability modification as generally related to a base station receiving an indication of a modified DC capability from a UE.

[0059] At block **602**, a base station (e.g., base station **121**) receives, via an RF transceiver, an Attach Request message from a UE (e.g., UE **110**) including a first indication of a Dual Connectivity (DC) capability of the UE.

[0060] At block **604**, in response to the reception of the first indication of the DC capability, the base station establishes DC communication for the UE, including configuring another base station (e.g., base station **122**) as a Secondary Node (SN) via an inter-base station interface (e.g., an X2-C or Xn-C interface).

[0061] At block **606**, the base station receives, using other than Radio Resource Control (RRC) signaling, a second indication of the DC capability of the UE that indicates a modification of the DC capability of the UE. For example, the base station receives the second indication in UCI, MAC CE, or using an allocated RACH resource via a PRACH.

[0062] At block **608**, the base station relays the second indication of the DC capability of the UE to a core network using the core network interface (e.g., interface **270**). For example, the base station may relay the second indication of the DC capability of the UE to the MME **152** in an EPC **151** via the S1-MME interface, or the base station may relay the second indication of the DC capability of the UE to the AMF **156** in an 5GC **155** via the NG-C interface depending on its MR-DC configuration.

[0063] At block **610**, based on the reception of the modified DC capability of the UE, the base station configures, via the inter-base station interface (e.g., interface **268**), the other base station to discontinue DC with the UE.

[0064] Although aspects of dual connectivity capability modification have been described in language specific to features and/or methods, the subject of the appended claims is not necessarily limited to the specific features or methods described. Rather, the specific features and methods are disclosed as example implementations of dual connectivity capability modification, and other equivalent features and methods are intended to be within the scope of the appended claims. Further, various different aspects are described, and it is to be appreciated that each described aspect can be implemented independently or in connection with one or more other described aspects.

1. A method for communicating a modification of dual connectivity (DC) capability by a user equipment (UE) in a cellular network, the method comprising:

transmitting, by the UE, an Attach Request message to a first base station, the Attach Request message including a first indication of a DC capability of the UE;

in response to the transmitting the first indication, establishing DC communication with the first base station and a second base station;

determining, by the UE, to modify the DC capability of the UE;

transmitting, at a physical layer or a Media Access Control (MAC) layer, the modified DC capability of the UE as a second indication of the DC capability of the UE; and

based at least in part on the modified DC capability of the UE, discontinuing DC communications using the first base station and the second base station.

2. The method of claim **1**, the method comprising:

transmitting, by the UE, the second indication of the DC capability of the UE in Uplink Control Information (UCI) at the physical layer or in a Control Element (CE) at the Media Access Control (MAC) layer.

3. The method of claim **1**, wherein the first base station allocates a Random Access Channel (RACH) resource to signal DC capability, the method comprising:

transmitting, by the UE, the second indication of the DC capability of the UE using the allocated RACH resource using a Physical Random Access Channel (PRACH).

4. The method of claim **1**, wherein the transmitting the second indication of the DC capability of the UE is effective to cause the first base station to relay the second indication of the DC capability of the UE to a core network.

5. The method of claim **4**, wherein the first base station is an Evolved Universal Terrestrial Radio Access (E-UTRA)

base station, and wherein the core network is an Evolved Packet Core (EPC) network including a Mobility Management Entity (MME).

6. The method of claim **4**, wherein the first base station is a Fifth Generation New Radio (5G NR) base station, wherein the core network is a 5G NR core (5GC) network including an Access and Mobility Management Function (AMF).

7. The method of claim **4**, wherein the first base station is an Evolved Universal Terrestrial Radio Access (E-UTRA) base station, wherein the core network is a Fifth Generation New Radio (5G NR) core (5GC) network including an Access and Mobility Management Function (AMF).

8. The method of claim **7**, wherein the second base station is a 5G NR base station, the method comprising:

transmitting, by the UE, the second indication of the DC capability, at the physical layer or the MAC layer, to the second base station that is effective to cause the second base station to relay the second indication of the DC capability of the UE to the AMF using an S1-C-modified-EN-DC-Capability message.

9. The method of claim **1**, further comprising:

determining, by the UE, to further modify the DC capability of the UE; and

transmitting the further modified DC capability of the UE as a third indication of a DC capability of the UE using RRC signaling, Uplink Control Information (UCI), a Media Access Control (MAC) layer Control Element (CE), or an allocated Random Access Channel (RACH) resource using a Physical Random Access Channel (PRACH), that is effective to reestablish DC communications.

10. The method of claim **1**, wherein the determining comprises:

sensing a temperature by the UE; or sensing an in-device coexistence issue from one or more radio transceivers in the UE.

11. A base station configured as a Master Node (MN) for Dual Connectivity (DC) communication, the base station comprising:

a radio frequency (RF) transceiver;

a core network interface;

an inter-base station interface; and

a processor and memory system to implement a base station manager application configured to:

receive, using the RF transceiver, an Attach Request message from a user equipment (UE) including a first indication of a DC capability of the UE;

in response to the reception of the first indication of the DC capability of the UE, establish DC communication for the UE, including configuring another base station as a Secondary Node (SN) using the inter-base station interface;

receive, at a physical layer or a Media Access Control (MAC) layer, a second indication of the DC capability of the UE that indicates a modification of the DC capability of the UE;

relay the second indication of the DC capability of the UE to a core network using the core network interface; and

based on the reception of the second indication, configure, using the inter-base station interface, the other base station to discontinue DC with the UE.

12. The base station of claim **11**, wherein the second indication of the DC capability of the UE is received in Uplink Control Information (UCI) at the physical layer from the UE or in a Control Element (CE) at the Media Access Control (MAC) layer from the UE.

13. The base station of claim **11**, wherein the base station manager application is configured to:

allocate a Random Access Channel (RACH) resource to signal DC capability by the UE; and

receive the second indication of the DC capability of the UE using the allocated RACH resource using a Physical Random Access Channel (PRACH).

14. The base station of claim **11**, wherein the base station is an Evolved Universal Terrestrial Radio Access (E-UTRA) base station, wherein the core network is an Evolved Packet Core (EPC) network including a Mobility Management Entity (MME), wherein the core network interface is an S1-MME interface, and wherein the base station manager application is configured to:

relay, using the S1-MME interface to the MME, the second indication of the DC capability of the UE using an S1-C-modified-EN-DC-Capability message.

15. The base station of claim **11**, wherein the base station is an Evolved Universal Terrestrial Radio Access (E-UTRA) base station, wherein the core network is a Fifth Generation New Radio (5G NR) core (5GC) network including an Access and Mobility Management Function (AMF), wherein the core network interface is an NG-C interface, and wherein the base station manager application is configured to:

relay, using the NG-C interface to the AMF, the second indication of the DC capability of the UE using an NG-C-modified-EN-DC-Capability message.

16. The base station of claim **11**, wherein the base station manager application is configured to:

receive, using the RF transceiver, a third indication of a DC capability of the UE using Radio Resource Control (RRC) signaling, Uplink Control Information (UCI), a Media Access Control (MAC) Control Element (CE), or an allocated Random Access Channel (RACH) resource using a Physical Random Access Channel (PRACH); and

establish DC communication for the UE, including configuring the other base station as the SN using the inter-base station interface.

17. The base station of claim **11**, wherein the second indication of the DC capability of the UE is received using the RF transceiver or wherein the second indication of the DC capability of the UE is received using the inter-base station interface from the other base station.

18. A method for communicating a user equipment (UE) capability for multi-Radio Access Technology (Multi-RAT) Dual Connectivity (DC) by a base station, the method comprising:

receiving, by the base station, an Attach Request message from the UE including a first indication of a DC capability of the UE;

in response to the receiving the first indication, establishing DC communication for the UE, including configuring another base station as a Secondary Node (SN);

receiving, at a physical layer or a Media Access Control layer, a second indication of the DC capability of the UE that indicates a modification of the DC capability of the UE;

relaying the second indication of the DC capability of the UE to a core network; and

based on the receiving the second indication, configuring, using an inter-base station interface, the other base station to discontinue DC with the UE.

19. The method of claim **18**, the method comprising:

receiving, by the base station, the second indication of the DC capability of the UE in Uplink Control Information (UCI) at the physical layer or in a Control Element (CE) at the Media Access Control (MAC) layer.

20. The method of claim **18**, the method comprising:

allocating, by the base station, a Random Access Channel (RACH) resource to signal DC capability by the UE; and

receiving the second indication of the DC capability of the UE using the allocated RACH resource using a Physical Random Access Channel (PRACH).

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